Westinghouse
Electric Corporation

Research and Development Center

Beulah Road
Pittsburgh Pennsylvania 15235

January 29, 1976

Mr. Larry R. Scudder (1 533M)
MS 302-1
NASA-Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

Dear Mr. Scudder:

SUBJECT: CONTRACT #NAS3-19439 - WESTINGHOUSE #DYD-10497-CE
Delivery of the Interim Report

Twenty (20) copies of the Sixth Month Interim Report for the subject contract are enclosed. Also attached are copies of the NASA Forms 533M.

Additional distribution of the Interim Report has been made according to the list that appears at the back of the report.

Cordially yours,

LaVerne R. Shipley

LaVerne R. Shipley
Research Contracts Management

/krb

enclosures

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	Attn: Audit Branch, MS 500-303	1
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cc: C. S. Duncan, Research Laboratories, Building #401

(NASA-CR-134924) DESIGN, FABRICATION AND TEST OF PROTOTYPE FURNACE FOR CONTINUOUS GROWTH OF WIDE SILICON RIBBON Interim Report (Westinghouse Research Labs.) 35 p HC $4.00 CSCL 20B G3/76

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Project Manager, Larry R. Scudder, Energy Conversion & Environmental Systems Division, NASA-Lewis Research Center, Cleveland, Ohio 44135

16. Abstract

This six-month interim report covers progress during the apparatus design, fabrication and assembly phases of a program to grow wide, thin silicon dendritic web. The growth facility has been essentially completed without any significant problems arising. A complete set of detailed fabrication drawings is included as an appendix to the report.

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TABLE OF CONTENTS

PROTOTYPE FURNACE FOR GROWTH OF WIDE SILICON RIBBON

C. S. Duncan and R. G. Seidensticker
Contract NAS 3-19439
Six Month Interim Report

1. SUMMARY

The overall objective of this program is to demonstrate the ability to grow silicon dendritic web crystals (ribbon) in an essentially quasi-continuous automatic facility and determine the applicability of such a process to solar cell fabrication. The specific objective is to design, build, operate, and evaluate a laboratory facility that will grow wide, thin silicon dendritic web and includes crucible replenishment capability as well as automatic control loops for the pulling parameters. The present Interim Report documents the progress which has been made during the first six months of the program.

The conceptual design of the system was developed under a previous contract (NAS 3-18034); the first task in the present effort was to translate this concept into a working design drawing package. At the conclusion of this design phase, the formal working drawings were approved by NASA-LeRC and fabrication of the apparatus was begun. At the end of the reporting period, the furnace chamber and its associated sub-assemblies had been assembled preparatory to performing thermal tests on the crucible and susceptor; however, testing has not yet begun.

Since the thermal geometry of the silicon melt is of prime importance to dendritic-web growth, the temperature distribution in the susceptor and in the melt will be determined prior to actual web growth studies. These tests will not only verify that the design goals have been achieved, but will also provide data to upgrade and validate analytical thermal models of the system.

2. INTRODUCTION

2.1 General

This six-month interim report summarizes the progress in design and fabrication of a laboratory facility for the quasi-continuous, automated growth of wide, thin silicon dendritic web. The ultimate goal for this equipment is to produce dendritic web at least 5 cm wide and approximately 150 μm thick at a rate of 2 to 3 cm/min for 120 hours under automatic control of the significant pulling parameters.

2.2 Background

The growth of semiconductory material in ribbon form has always been an attractive technique. When Billig reported the growth of germanium dendritic crystals in 1955,[1] an intensive study program was undertaken at the Westinghouse Research Laboratories to understand and develop this mode of growth. The result was a comprehensive evaluation of the characteristics of what was called "controlled dendritic growth" in semiconductors reported in a number of papers detailing growth mechanisms, impurity distributions, and crystal perfection.[2-9]

During the course of the studies, it was observed that occasionally two coplanar dendrites would grow simultaneously from a single seed with a film of liquid freezing between them. These "dendritic web crystals" were much wider than the dendrites themselves and were apparently much better suited for semiconductor device fabrication.[10-13] It was but a short time before not only germanium but also silicon was grown by this technique. Eventually, a pilot production facility was placed in operation and pilot quantities of solar cell arrays were produced. The anticipated market for these

devices did not develop and the development of techniques for growing large diameter Czochralski silicon reduced market potential of web crystals for other silicon devices. With this poor economic prognosis, the silicon web program was terminated.

At the conclusion of these web crystal programs, pilot production facilities were routinely producing high quality material of 1 cm usable width and 6 to 15 meters in length. Wider material, up to 3 cm, was being grown on a laboratory scale. It was apparent that while there did not seem to be any fundamental limitations to the process, nevertheless, new concepts in apparatus were necessary to grow significantly wider and longer crystals than those being produced.

In the early 1970's the need for new, nonpolluting energy sources became apparent. Direct photovoltaic conversion of solar energy is an attractive technique if it can be made economically viable. One possibility in this direction would be the automated production of silicon solar cells. Silicon web crystals offered possibilities in this direction if greater material through-put could be achieved.

The opportunity to pursue this problem arrived with a study program under the aegis of the NASA-Lewis Research Center (Contract NAS 3-18034). The objectives of that program were to quantitatively define the conditions required for dendritic web growth and develop conceptual designs for appropriate growth systems. The growth system should in concept be capable of growing 5 cm wide web approximately 150 μm thick at rates of 2 to 3 cm/min. Appropriate crucible replenishment concepts leading to quasi-continuous operation were to be identified as were control concepts for automated operation. At the conclusion of the study program, the present effort was instituted to design and construct a laboratory dendritic web growth apparatus to implement the design concepts.

2.3 Scope of Present Work

The present program encompasses a number of tasks presented in the Work Plan.[14] Although only Tasks A, B, and part of C are covered by this report, the entire program can be described as follows.

Task A -- Design of Prototype Furnace

The goal of this task is to develop a detailed design suitable for the construction of a prototype furnace for growing single crystal silicon ribbon by the web-dendrite process from a melt which is automatically recharged without causing interruption of the growth process. The technical approach to this design is based on the results of Contract NAS 3-18034.

Task B -- Fabrication of Prototype Furnace

The goal of this task is to fabricate and assemble a prototype furnace according to the design developed in Task A. This assembly will include all components necessary for semi-automatic operation of the system.

Task C -- Test and Evaluate the Prototype Furnace in Semi-Automatic Operation

A goal of this task will be to operate the furnace system semi-automatically to verify the heater-crucible design and grow dendritic web crystals to demonstrate the viability of the apparatus. Another goal of this task will be to investigate the requirements of the three subsystem control loops which will ultimately be used for automatic quasi-continuous operation of the furnace. The final goal will be to devise the apparatus and operating techniques needed to satisfy the requirements of the subsystem control loops and evaluate each independently.

Task D -- Operate Prototype Furnace in Automatic Quasi-Continuous Mode

The initial goal of this task is to design, construct and assemble all the remaining components and instrumentation determined

under Task C, as required for automatic operation of the control loop subsystems. With the subsystems and the basic furnace completely integrated, the furnace system will be tested under actual operating conditions and all subsystems operating in combination with each other. The other goal of this task is to demonstrate quasi-continuous growth and optimize growth conditions for the purpose of growing ribbon 0.01 cm or greater in thickness, single crystal, and have smooth surfaces free of any gross defects.

Task E -- Conclusions and Recommendations

This task has two goals, the first being an oral review of the program, at the Westinghouse Research Laboratories, for Govenrment and invited industry personnel. A demonstration of the furnace will be included in this review. The second requ_rement of this task will be to prepare, as a part of the final report, a specific recommendation for a pilot line furnace design based on the results of this program.

Task F -- Reports

The following reports of work will be provided for this program:

1. Work Plan.
2. Monthly technical progress narratives and financial reports. The sixth month is excluded.
3. Two Interim Reports:
    a. After completion of the sixth contract month.
    b. After completion of Task C.
4. Final Report.
5. Oral Review.

The anticipated time schedule for completion of the tasks is shown in Fig. 1.

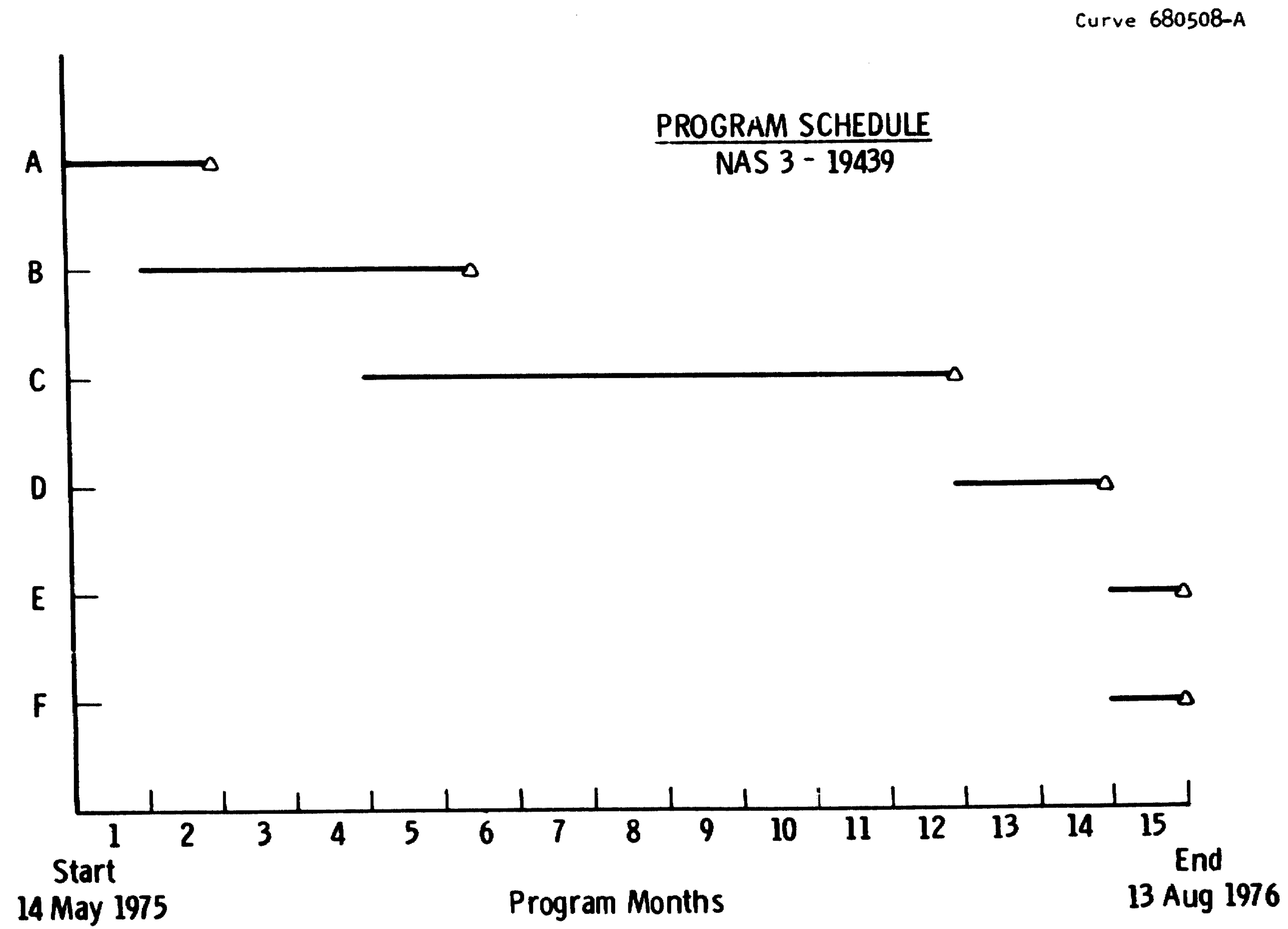

Fig. 1. Program Schedule.

3. DISCUSSION

In the following sections, the design objectives, concepts, and their implementation are discussed. Also, the test plan for verifying the thermal geometry of the crucible/susceptor is presented.

SYSTEM DESIGN

3.1 Design Objectives

The detailed facility design is based on the design concepts developed under Contract NAS 3-18034. The three key objectives, which this design satisfies, are, in brief:

Demonstrable Capability. Apparatus constructed according to this design will be capable of demonstrating, by means of actual web growth, the ability to produce silicon dendritic web as predicted by the study conclusions of Contract NAS 3-18034.[15]

Provide Design Data. The facility defined by this design is best described as a laboratory prototype apparatus. As such, one of its purposes is to have sufficient versatility and complexity that it can utilize and evaluate a variety of alternative methods or design features. It will allow the facility to be tailored to fit growth requirements and it will identify the design data needed to develop a detailed design for an efficient, relatively simple and economical production prototype web growth facility.

Provide Cost Data. The versatility of the laboratory prototype facility built according to this design will allow use of selected process features which will provide data essential to an economic evaluation of the web growth process.

3.2 Basic Approach to Design

Wide versatility and flexibility are major features of this design. To obtain these features the main housing of the growth chamber was selected as a water-cooled, stainless steel rectangular envelope of 18 x 18 x 24 inches. Each of the six faces has a large circular opening which is hermetically closed by a readily removable cover plate. The cover plates provide access for a majority of the required growth chamber penetrations (water, gas, power and instrumentation leads, web, raw material feed, etc.). Also, much of the required internal and external mechanism is mounted on the cover plates. Thus, it is not only possible but, more importantly, relatively convenient and inexpensive to exchange a large portion of the operating features of the facility. Thus, both major and minor design modifications and adjustments may be efficiently implemented. Another advantage of this design is excellent accessibility -- some covers are essentially blank -- which enhances modifications, adjustments, cleaning and set-up for operation.

3.3 Structural Features

Simplified sketches, Figs. 2, 3, and 4, are provided as an aid to understanding the following description of the key features of the system design. Full engineering detail drawings are included in Appendix A.

Growth Chamber. The basic approach to the design and the functional features of the growth chamber were discussed above. The growth chamber is permanently affixed to a heavy metal frame which also supports supplementary apparatus such as the vacuum pumping system and the web withdrawal and storage reel. The frame may, if needed, be heavily weighted in the lowermost portion of its structure as a means of lowering the center of gravity and reducing vibration. Space is provided for shock mounting if necessary.

Work Coil Positioning. The work coil mounting and positioning structure is mounted on the bottom cover plate inside the lower region

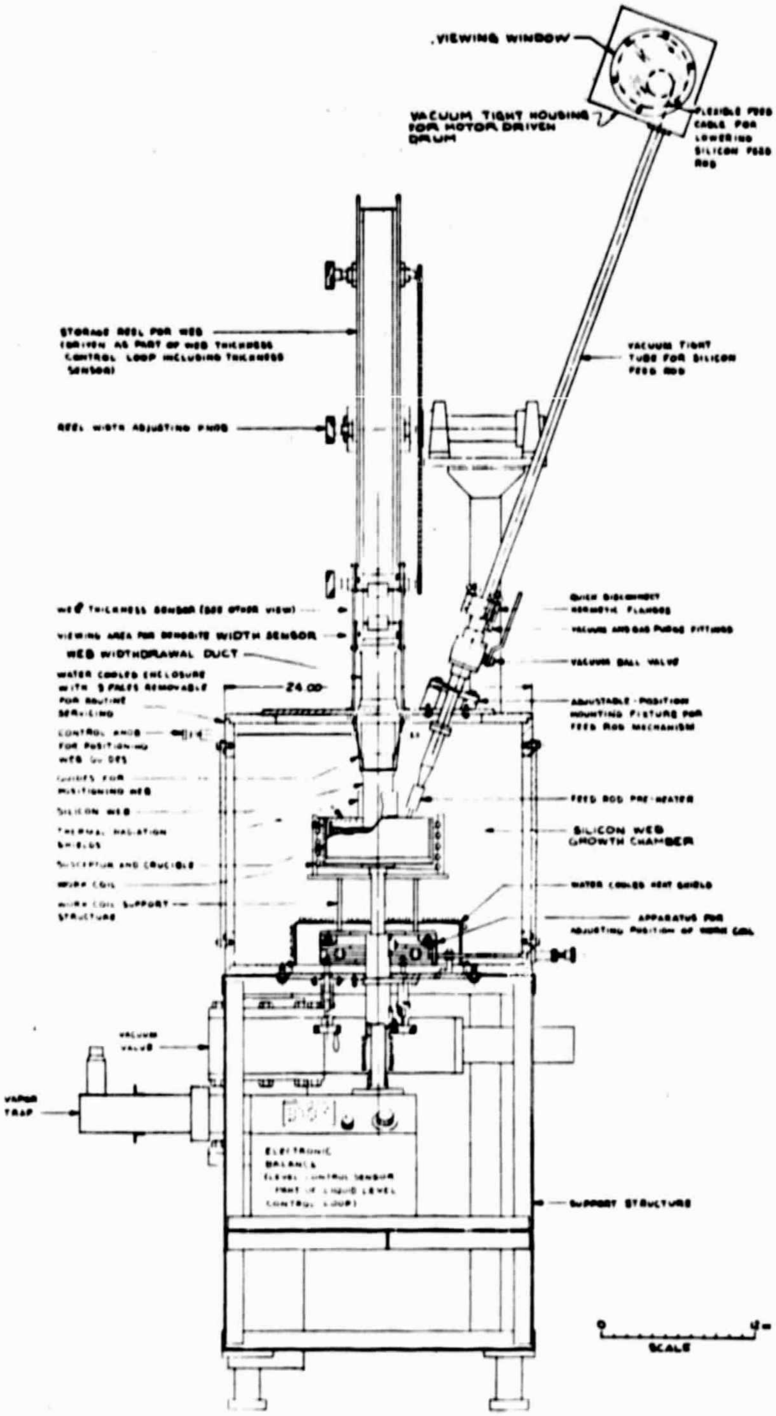

Fig. 2. Silicon Web Furnace: simplified front view.

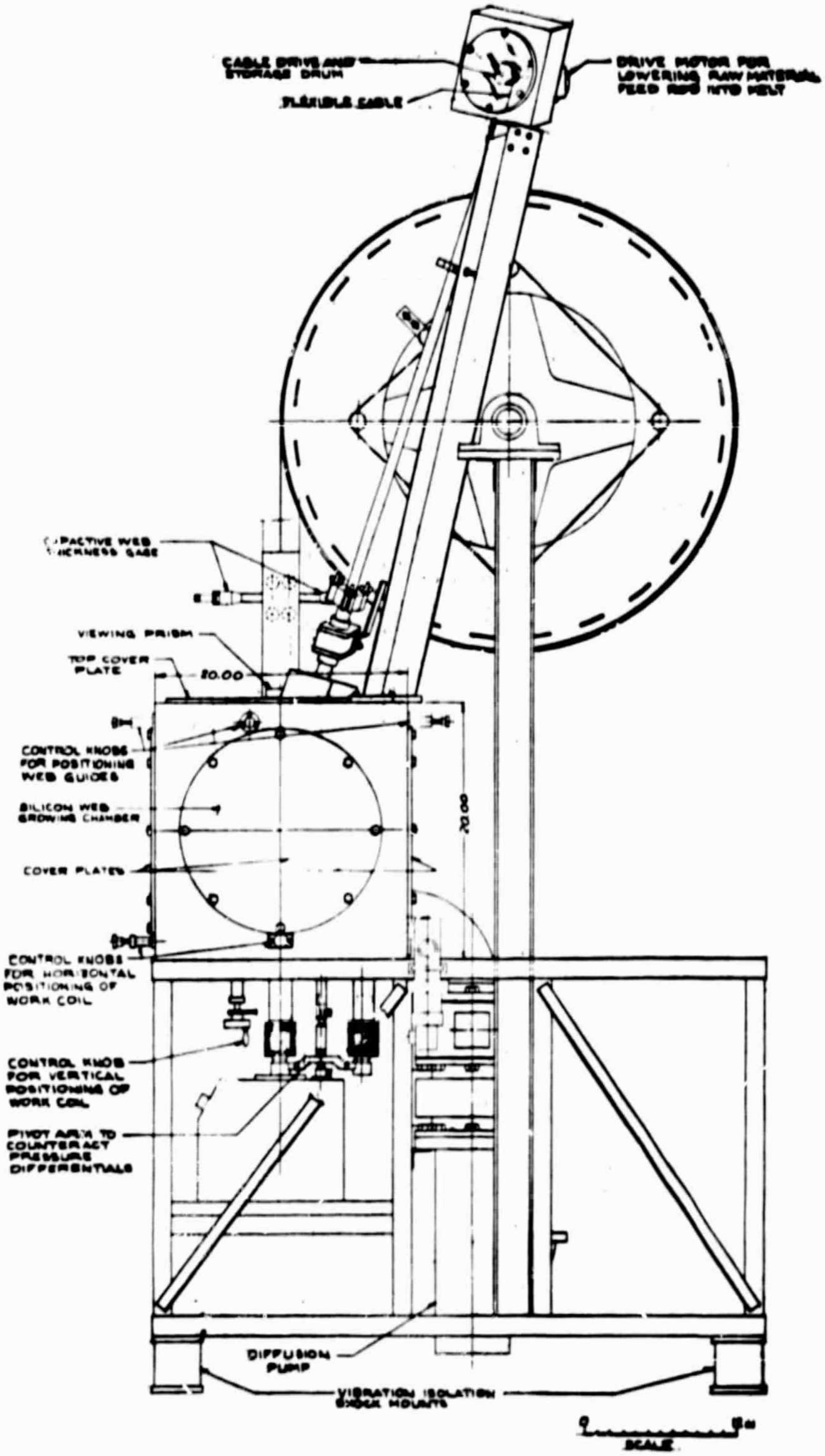

Fig. 3. Silicon Web Furnace: simplified side view.

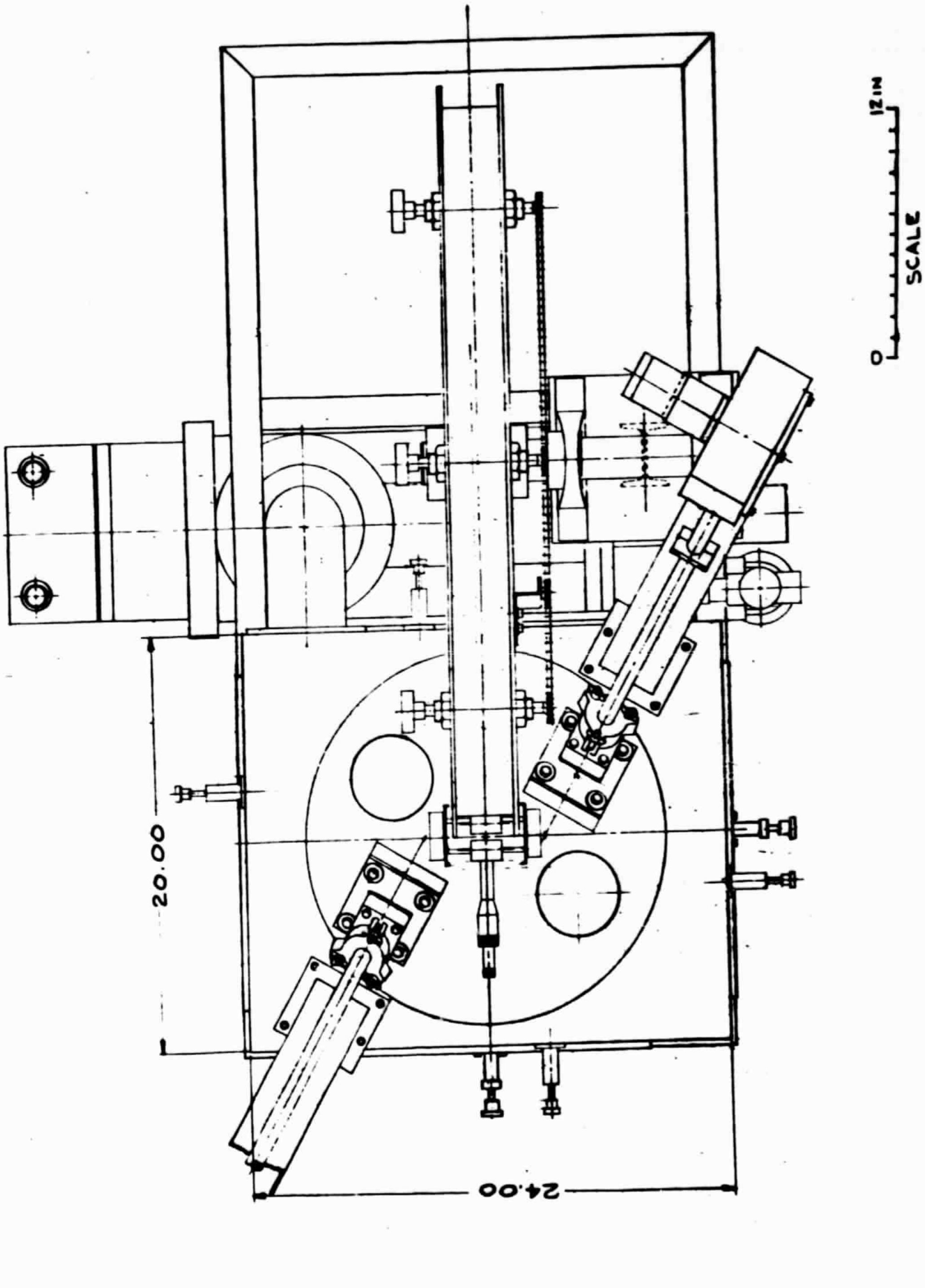

Fig. 4. Silicon Web Furnace: simplified top view.

of the growth chamber. Three-direction position adjustment is provided by way of externally located manually operated control knobs. Horizontal positioning is needed as a means for obtaining thermal symmetrical balance within the crucible; vertical positioning is useful as a means for adjusting the vertical gradient within the crucible.

Crucible and Susceptor. The fundamental design requirements were developed under Contract NAS 3-18034.[15] They may be simply stated as a relatively small vertical temperature gradient along the center line of the melt and an overall cylindrical symmetry to match the geometry of the web. The conceptual design which was developed to meet these requirements is shown in Fig. 5.

The actual crucible/susceptor system follows the conceptual design very closely as can be seen from the detail drawings in Appendix A. One of the important features of the design is a totally enclosed top shield assembly to reduce possible degradation of the shield stack by silicon monoxide evolved from the melt. Nevertheless, the shield stack can be easily disassembled to replace or add new elements. This feature permits control over the vertical gradient in the melt which depends on the surface heat loss. Another feature of the design is the three-point kinematic support which permits easy removal of the susceptor with precise repositioning.

Web Withdrawal Route and Mechanism. A 36-inch diameter speed-controlled reel serves the dual purpose of a storage and a withdrawal mechanism for web as it grows. The web is routed vertically through a withdrawal duct which is provided with sufficient gas flow to prevent harmful entry of air into the growth chamber. Adjustable positioning guides for the web are located inside the growth chamber below the withdrawal duct. Above the withdrawal duct additional guides automatically center the web as it leaves the duct and passes through control loop sensors. The storage and withdrawal reel is adjustable for a wide range of web widths and automatically centers for all width adjustments.

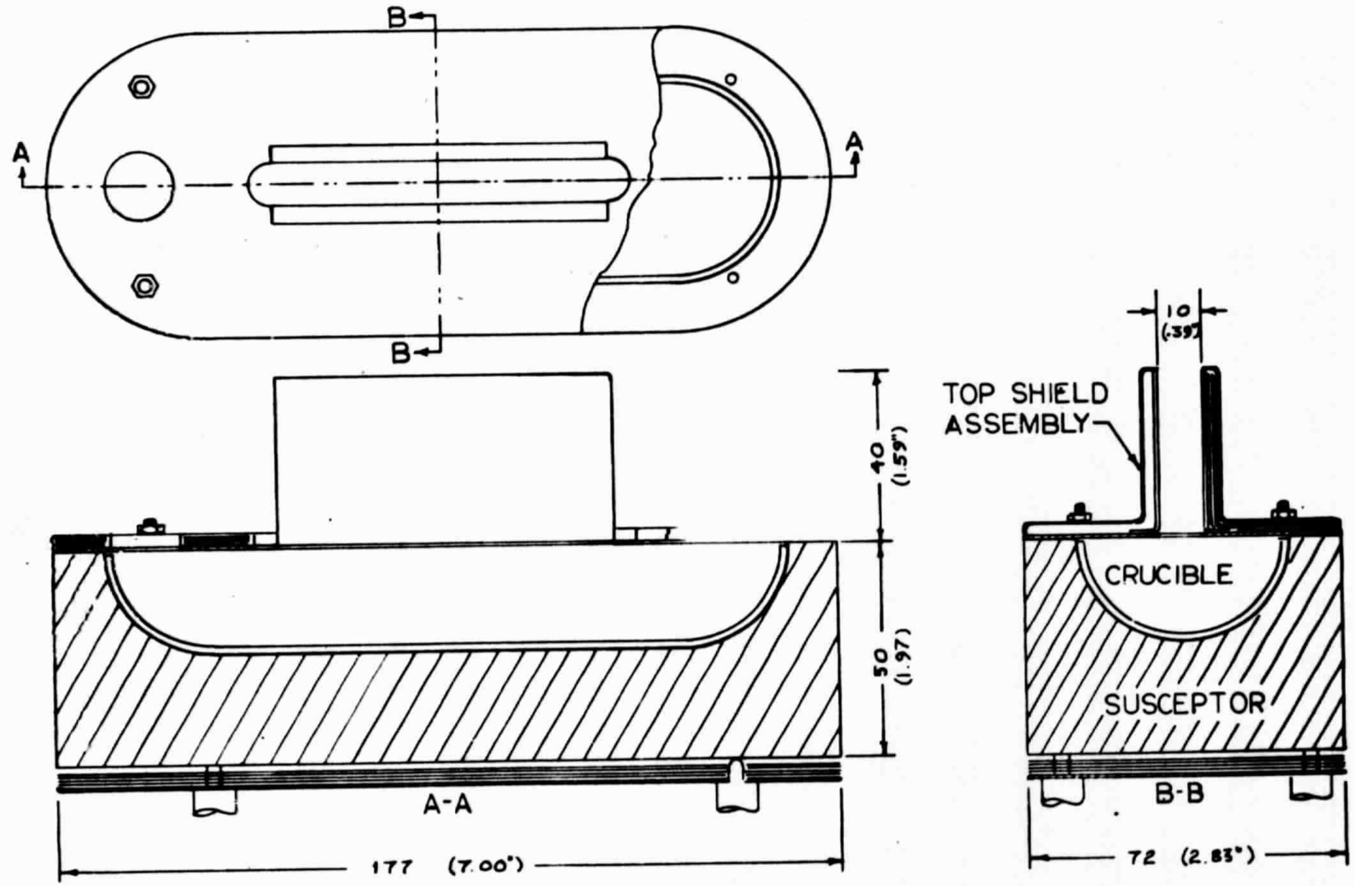

Fig. 5. Simplified crucible assembly.

Raw Material Feed Mechanism. The versatility of the conceptual design accommodates alternative methods for continuous replenishment of the melt with raw silicon. The method which was selected for initial use will utilize slim ($\sim$ 3 to 6 mm diameter) polycrystalline rods such as those which are mass produced as a key step in the commercial production of semiconductor grade silicon. The selected design utilizes rods of approximately one meter length and allows re-loading as often as necessary. Dual feed mechanisms, one at each end of the crucible, are to be used alternately in order to feed raw silicon by gravity at a continuous, uninterrupted rate. Raw material preheaters, located near the melt, can be provided for use with each feed mechanism and in addition to preheating the feed rods can be used continuously in order to help maintain thermal balance within the crucible. The feed mechanisms are mounted entirely on and through the top cover plate. If found to be desirable for the purpose of evaluation, the mechanisms can be converted to a pellet feed method.

Atmosphere. The growth chamber, feed mechanisms and the web withdrawal duct can be purged by high vacuum ($\sim 10^{-6}$ torr) prior to web growth. The design, as presently planned, will utilize an inert gas, argon, as an atmospheric medium during web growth. Except for the web withdrawal duct the design provides for full range of pressure from high vacuum to a maximum in excess of one atmosphere. A removable cover plate is available to temporarily seal the web withdrawal duct during purging prior to the establishment of web growth. The need of the capability of growing web under vacuum or reduced pressure has not at this time been established and is not planned. The current design will allow conversion to vacuum and reduced pressure under growth conditions, if later found to be necessary, although the cost would be relatively high.

Vacuum Pumping System. Vacuum pumping capability is a built-in part of the design. The high vacuum pumping includes a high conductance gate valve and liquid nitrogen vapor trap in conjunction with a

diffusion pump and mechanical pump. Vacuum roughing is handled by a separate mechanical pump, valve and pump line. Although not presently planned, a hot metal getter has been considered for use inside the growth chamber and can be added if later desired.

Viewing Capability. Ability to view the growth region of the melt is mandatory during the growth start-up procedure. After growth is established, viewing is essential not only for visible monitoring of the growth but additionally for adjusting the web positioning guides inside the growth chamber. To satisfy these needs viewing prisms will be located on the top access plate immediately adjacent to the withdrawal duct in order to provide viewpaths, parallel to the web, to the growth region of the melt surface. View ports will also be located in the top, front and each of the side access cover plates.

3.4 Sensing and Control

Web growth in this facility will ultimately be governed automatically by three separate but related control loops. Although the exact design of control loops is yet to be determined, adequate space and accessibility has been provided such that final choices can be installed and evaluated without difficulty. Initially, web growth will be controlled semi-automatically with manual operation decisions based on observations as well as sensor outputs not tied into control loops. The information gained by this experience will result in the finalizing of the control loops design and, subsequently, automatic control of the full process. The three control loops are discussed in the following sections.

Dendrite Width/Melt Temperature Control Loop. Within the normal range of withdrawal rate the width of the dendrites will depend primarily upon the melt temperature. It is presently anticipated that a scanning optical sensor will be used to measure dendrite width and will be located immediately above the web withdrawal duct. For the

system to function for web growth it is necessary that the melt temperature be held within a very narrow range essentially at the melting point of silicon. This will be performed by means of a relatively conventional temperature control loop system similar to those commonly used for Czochralski growth of silicon. The dendrite width sensor will be joined with the conventional system as a subsystem loop to provide control point offset as required to maintain the desired dendrite width. Because the dendrite sensing occurs several minutes after growth the response rate for correction of control point offset must be adjusted accordingly.

Web Thickness/Withdrawal Rate Control Loop. Assuming that the melt temperature is held within the narrow range indicated in the previous paragraph, the web thickness will depend primarily upon the withdrawal rate. An electronic capacitive thickness sensor will be located immediately above the dendrite width sensor and will be used in a control loop with the motor and mechanism which drives the withdrawal and storage reel. The response rate for this loop must also be adjusted to compensate for the fact that sensing occurs several minutes after growth.

Melt Level/Material Feed Rate Control Loop. An electronic balance will be employed to provide continuous sensing of the crucible weight and, consequently, the melt level. The electronic balance is located below the growth chamber and will provide a dc voltage indicative of the melt level. The control loop will combine the balance and the motor drive units which lower raw silicon rods into the melt. The weighing system will be insensitive to growth chamber internal-external pressure changes during operation by virtue of a pressure balancing arrangement which is built-in. An optical melt level sensor has been considered as an alternative to the weight sensor and could be used as a backup if needed.

Other Sensing and Measurements. During the evaluation and development phase of furnace use, it is expected that numerous temperature measurements will be required in several parts of the system, especially the crucible and susceptor. Adequate accessibility has been provided to serve this need.

3.5 Design and Construction Modifications

No critical design problems arose during the component fabrication and construction phase of the program. In the interest of design refinement, however, some minor modifications were adopted. The largest change was to abandon the width adjustment feature of the web storage reel and to substitute adjustable external guides in the interest of lower cost. The only other significant change was in details of the gas pressure equalizing system for the purpose of improving sensitivity and accuracy. Not all of these changes are included in the attached design drawings.

3.6 Test Program

3.6.1 General Considerations

The significant test of the web furnace design will be its ability to grow wide, thin dendritic web crystals in quasi-continuous operation with automatic control. This task forms the major effort for the following six-month period. Test activities in the present six-month period have been confined to fit/function testing of subassemblies and to the development of a test plan for preliminary thermal testing of the system.

Thermal Test Plan. The temperature distribution in the liquid silicon appears to be of considerable importance to successful growth of dendritic web crystals; however, measurements during crystal growth operations are impractical because of interactions between the measuring probe and the growing crystal. Since the melt temperature

field should be only slightly perturbed by the growth process at distances more than a few millimeters from the solid-liquid interfaces, measurements made without actually growing a crystal are still valuable. Further, since temperature gradients are of more interest than absolute temperatures, the average melt temperature can be kept hot enough to preclude the freeze out likely to occur if the supercooled melt were probed during growth.

The data generated by the measurement program described in the following sections has two important applications. The first is to provide empirical information on temperature distributions in both the liquid melt and in the molybdenum susceptor. For example, the axial temperature gradients can be measured in the liquid and related to changes in the work coil position. Also, the temperature differences between the liquid and the susceptor can be evaluated to relate melt temperatures during growth to a temperature which can be measured without affecting the growth process.

The second application of the data is the verification of thermal models of the crucible/susceptor system. Although analytical models of a thermal system are extremely useful in predicting system performance, the output of the model is no better than the input data. When observed and predicted performance can be compared, however, the critical thermal parameters in the model can be refined so that further modeling of different geometries, operating conditions, etc., can be done with greater precision.

3.6.2 Measurements Conditions

Ideally, all thermal measurements on the crucible/susceptor assembly would be done under conditions closely approximating the final operating conditions. Since this would imply that measurements should all be made with a silicon filled, quartz crucible present, practical economic considerations dictate that a large portion of the measurements be made otherwise. Once silicon has been melted in a quartz crucible,

it cannot be frozen without destroying the crucible. A more cost efficient procedure of measurements would be to perform an initial series of measurements with an empty susceptor, then a measurement series using a crucible filled with an inert liquid metal such as tin, and finally a measurement series with a silicon filled crucible.

The temperature measurements discussed in the previous sections would be performed prior to the final assembly of the furnace and would therefore require some temporary arrangements such as port covers.

Initial Measurements (Empty Susceptor). The measurement series with an empty susceptor will permit debugging the measurement equipment as well as providing useful temperature data. The measurements which would be made are:

1. Longitudinal traverse of crucible cavity (points labeled ∇ in Fig. 6). These measurements would be performed by optical pyrometry.
2. Vertical traverse of susceptor wall (points labeled 0 in Fig. 6). These measurements would be performed by optical pyrometry.
3. Vertical traverse of susceptor wall. These measurements would be made with a noble metal thermocouple probe in the thermocouple probe hole.

All these measurements would be made with a crucible temperature of about 1430°C. A second set of measurements, somewhat abbreviated from 1-3 above would be made at a temperature of about 1410°C to determine the effect of absolute temperature on the temperature gradients in the system.

Temperature Measurements in Molten Metal. The reactivity of liquid silicon complicates the measurement of temperature distributions in the material. Obviously, care must be exercised in providing protection for the temperature probe itself. Further, because of adhesion of the melt to the crucible, a given melt/crucible combination

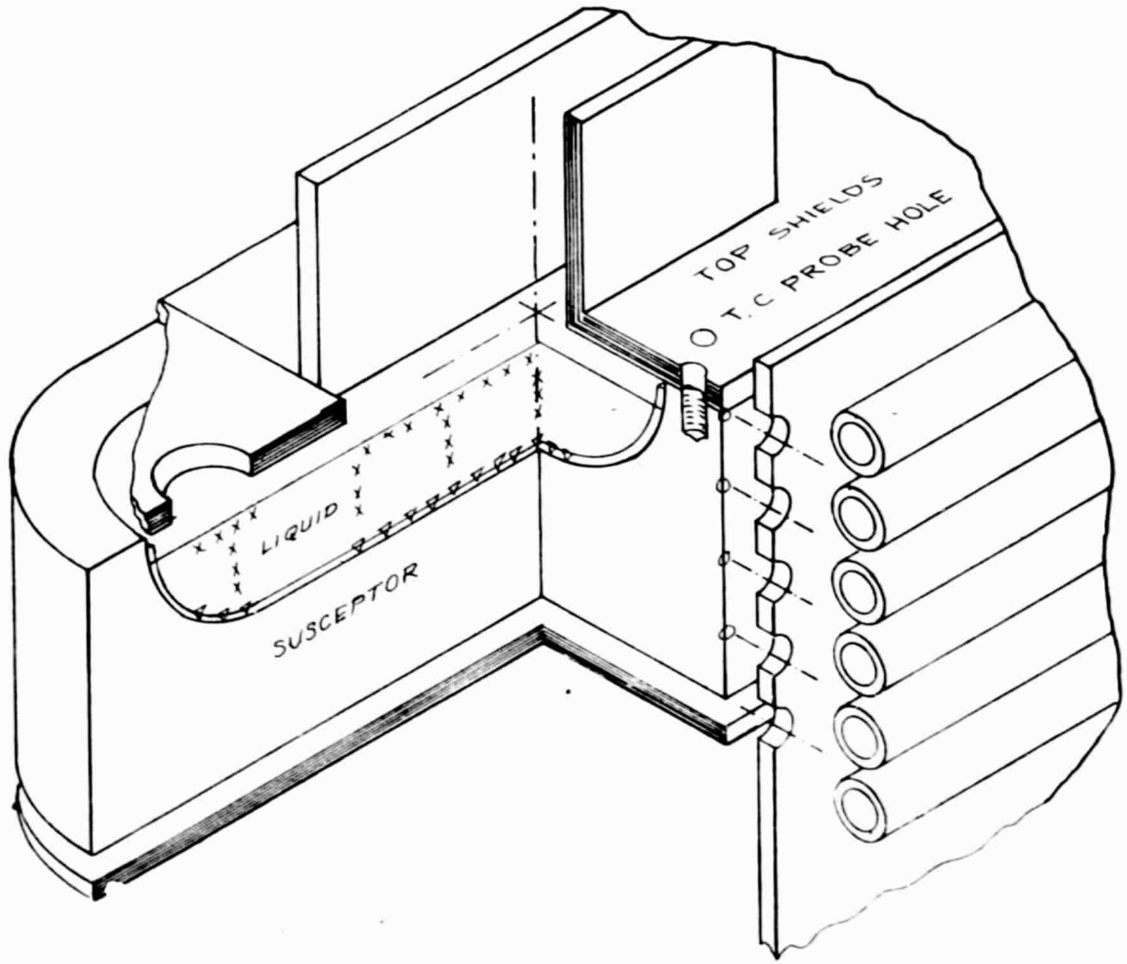

Fig. 6. Crucible/susceptor: thermal test pattern.

can be used only once, although some fraction of the melt may be reused. From these considerations, one would conclude that as few measurements as possible should be made consistent with obtaining adequate data.

Fortunately, there appears to be a procedure which will yield a considerable amount of data on the thermal properties of the crucible/susceptor configuration and yet avoid some of the problems with liquid silicon. This procedure is to use a model material such as tin as a test liquid. Liquid tin has thermal properties very similar to liquid silicon while being relatively inert and inexpensive (Table 1). This would permit a fairly detailed thermal mapping of the liquid melt with some assurance that a scaling factor near unity can be used to transform the results to silicon. Further, the crucible and melt should be reusable. In addition to the measurements themselves, experience is gained in the operation and performance of the instrumentation.

Table 1

		Si	Sn
Thermal Conductivity (1420°C)	ω/cm-K	~0.6	0.55
Electrical Conductivity (1420°C)	μΩ-cm	81	77
Emissivity (calculated) (1420°C)		0.22	0.22
Vapor Pressure (1420°C)	torr	.05	6

The anticipated measurements would include the crucible wall temperatures as in Fig. 6 and a traverse of the liquid over the paths indicated by x-x-x in Fig. 6. The measurement sequence would be done at several temperatures, e.g., about 1000°C, 1200°C, and 1400°C to check the temperature dependence and internal consistency of the measurements. If all the systems are working properly, the whole measurement series should require only about one day.

Temperature Measurements in Liquid Silicon. The final set of temperature measurements would be made with liquid silicon in the crucible. This data set would provide a scaling factor for the interpretation of the temperature measurements on tin as well as providing some direct measurements. The measurements would all be made at a temperature near the silicon melting point and would at a minimum consist of a vertical axial traverse and a vertical traverse near the feed hole.

4. SUMMARY OF RESULTS: CURRENT STATUS

The conceptual design for a silicon dendritic-web growth system was developed under Contract NAS 3-18034; the present effort is directed at implementing that concept. All the design drawings have been completed and approved by the cognizant NASA-LeRC personnel.*

All the furnace facility components with the exception of the Storage Reel have been fabricated and assembled for fit and function testing. The first major system test will be a thermal performance test. The test plan for this initial operation has been developed and the furnace configured accordingly (including several special test fixtures). This configuration is shown in Figs. 7 through 10. The work coil and several radiation buffles have been removed for clarity.

The thermal measurements should require about two weeks for completion, although interpretation will take somewhat longer. Once the measurements themselves are completed, however, the furnace will be reconfigured for actual growth studies and web pulling experiments will begin.

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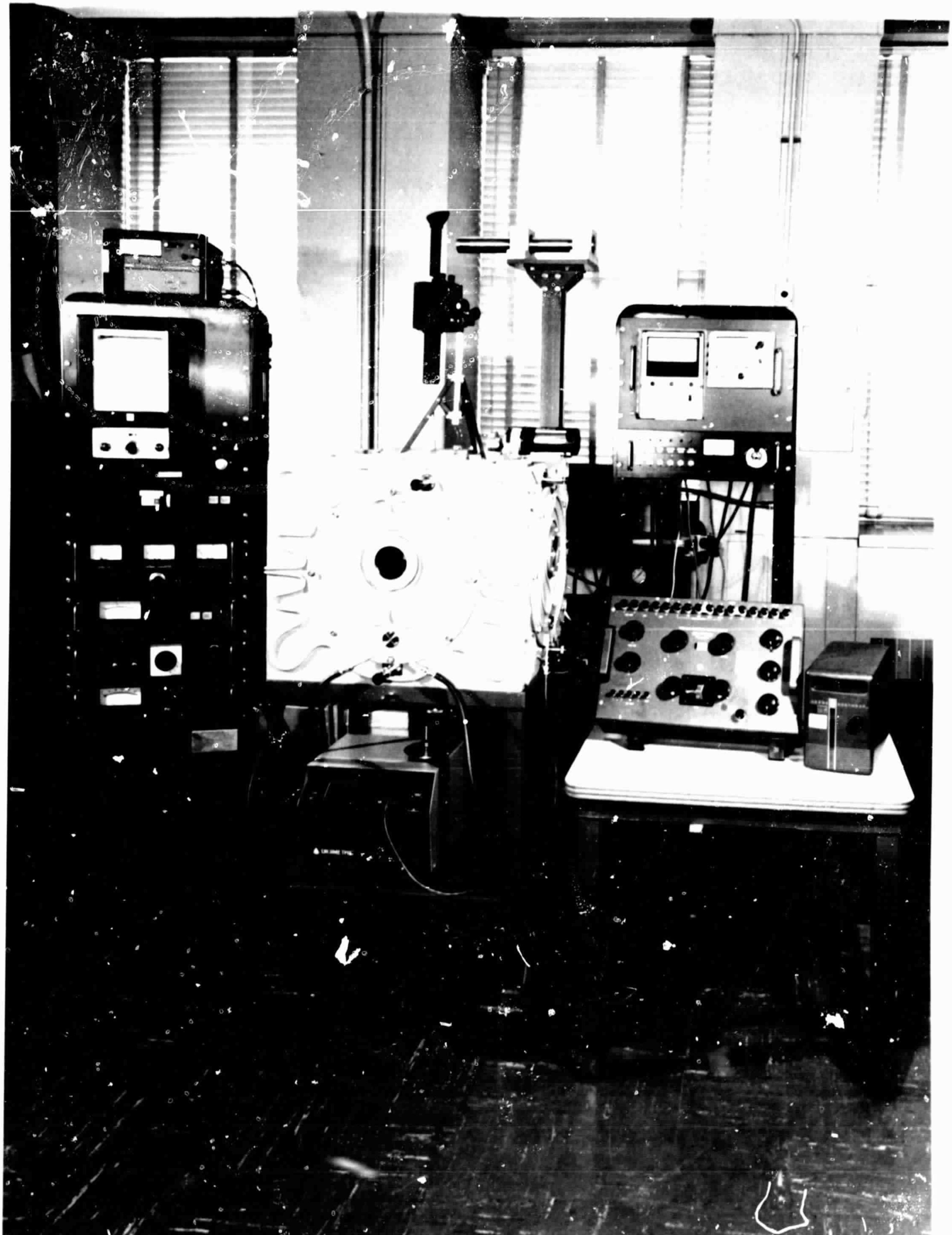
*Appendix A includes all the detail drawings for the Silicon Dendritic Web Furnace.



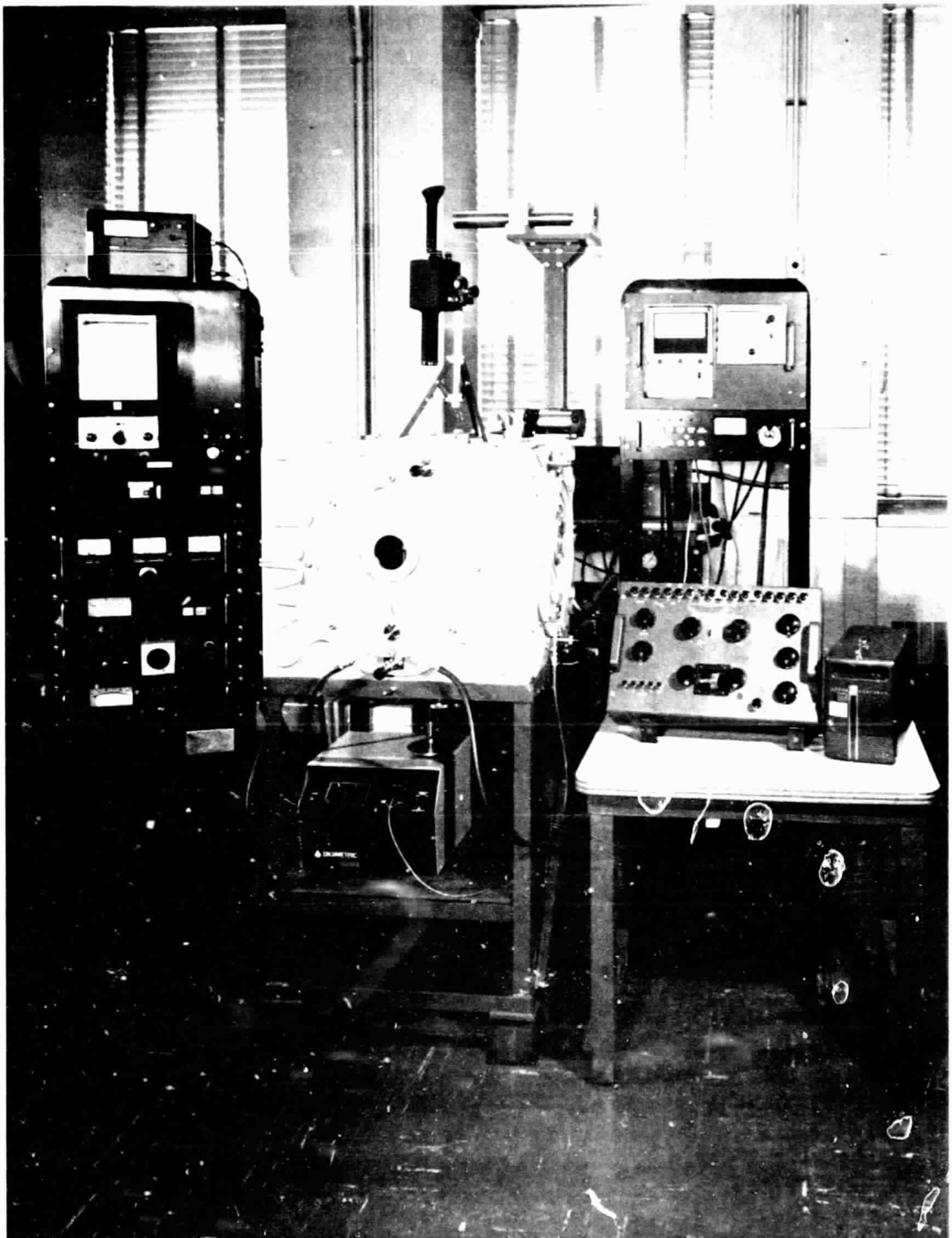
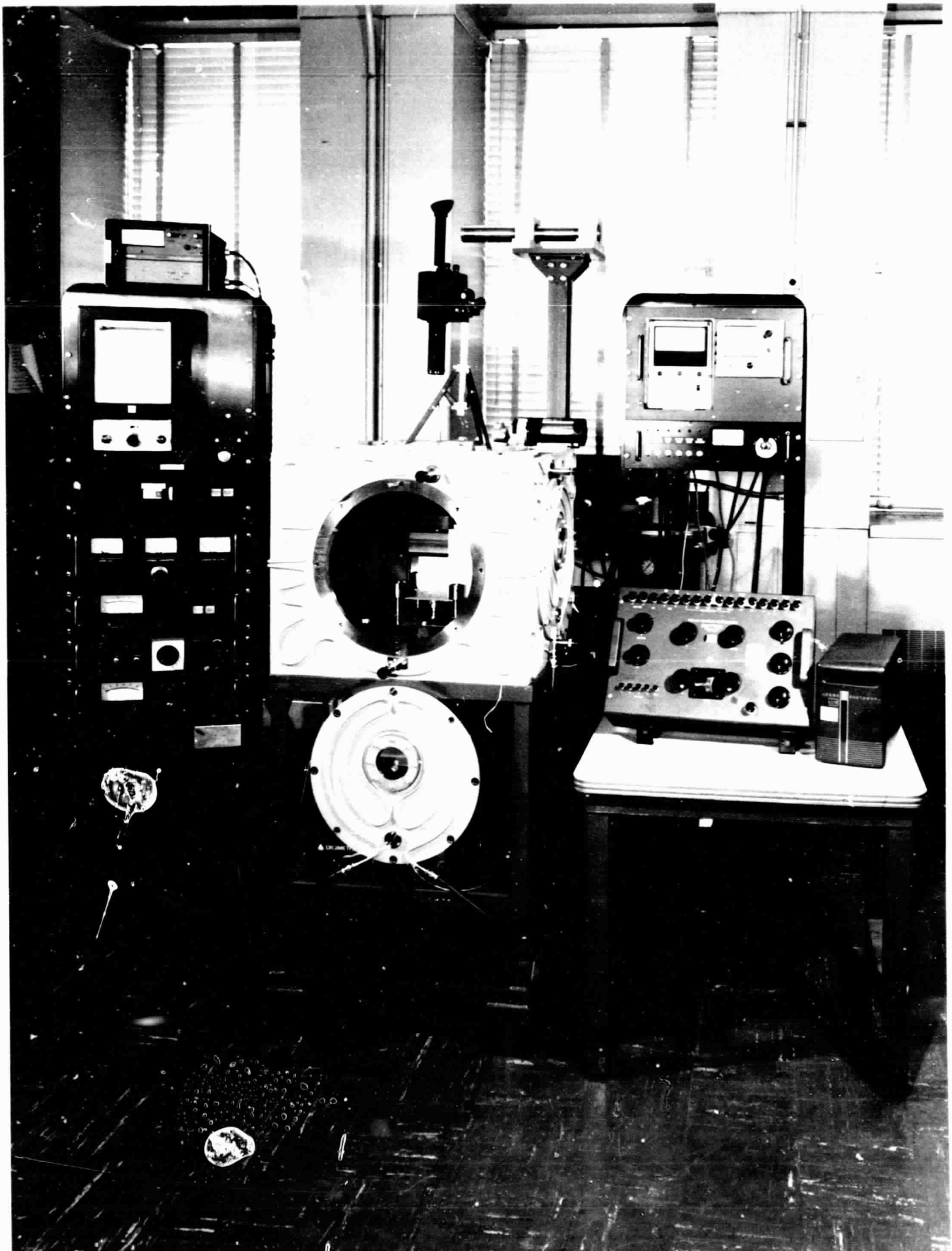


Fig. 7. Silicon web furnace.



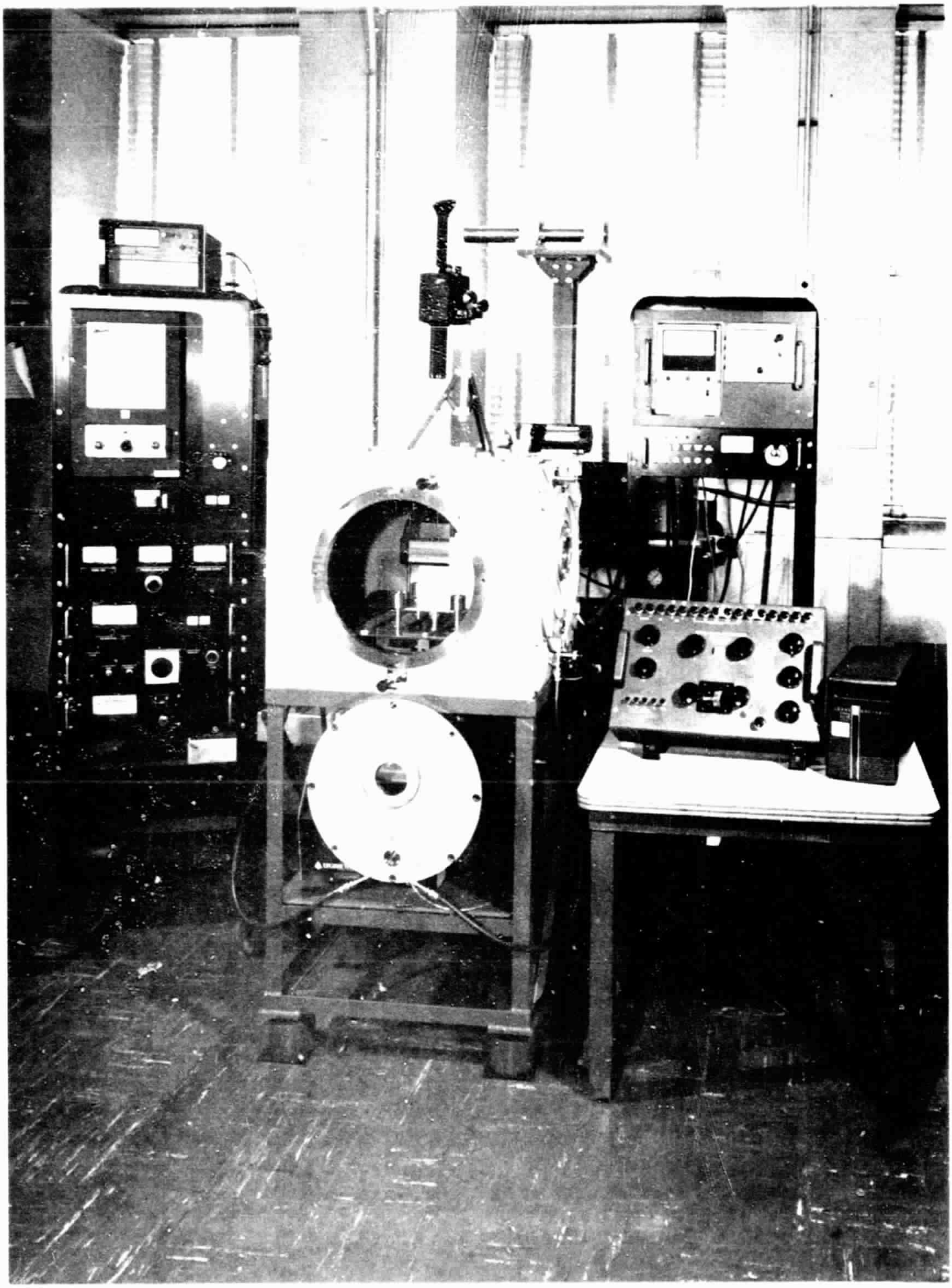


Fig. 8. Silicon web furnace (front cover removed).

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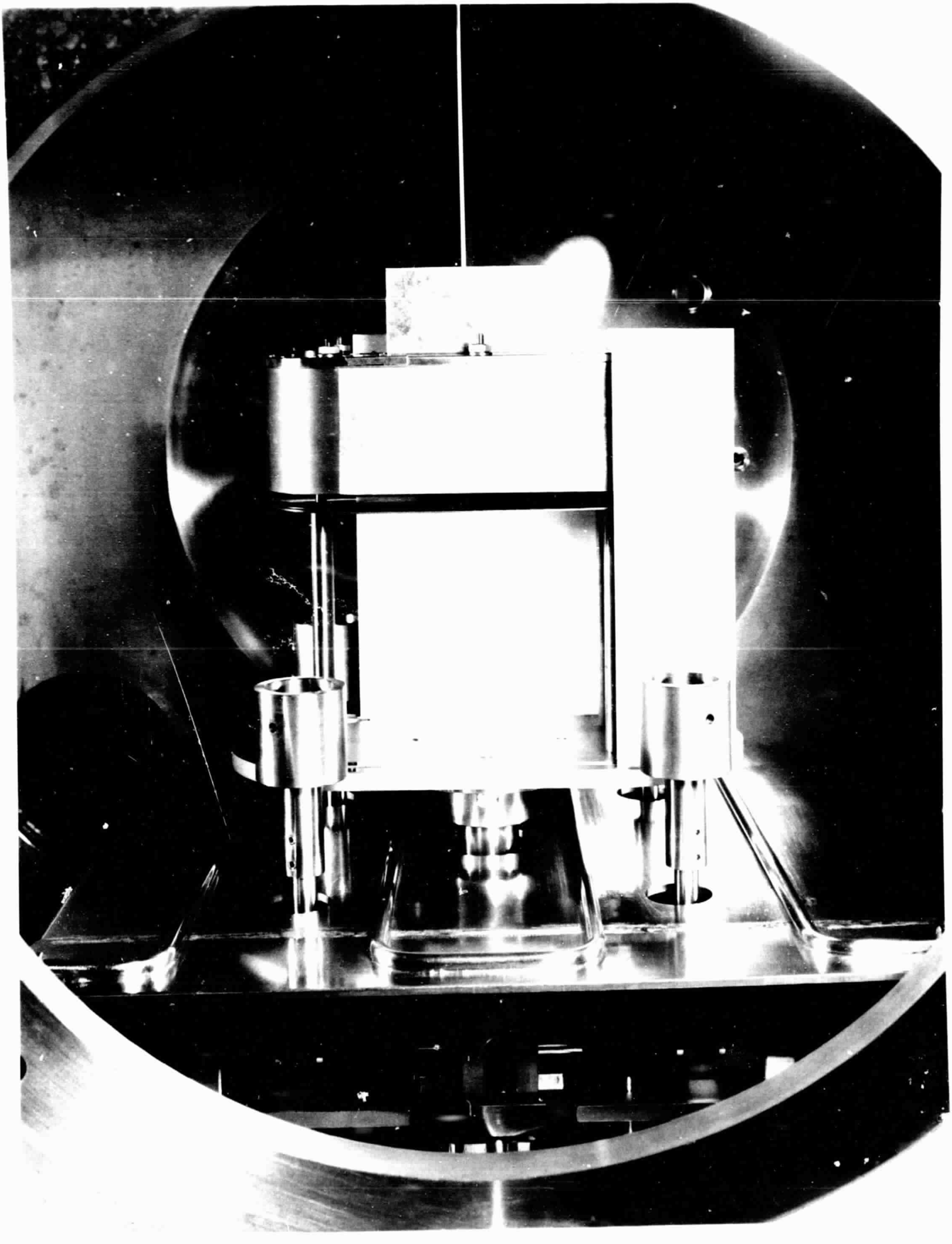


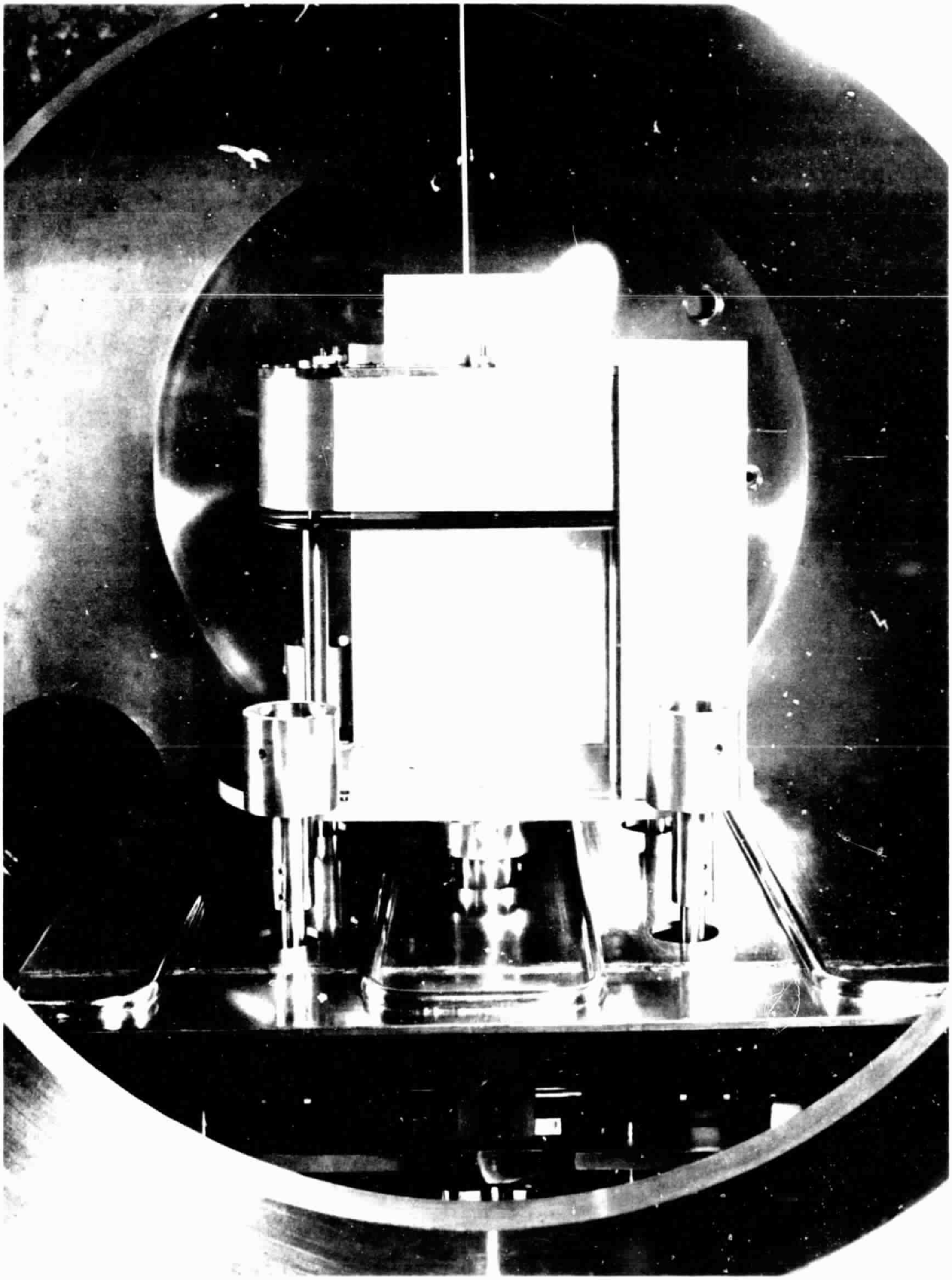
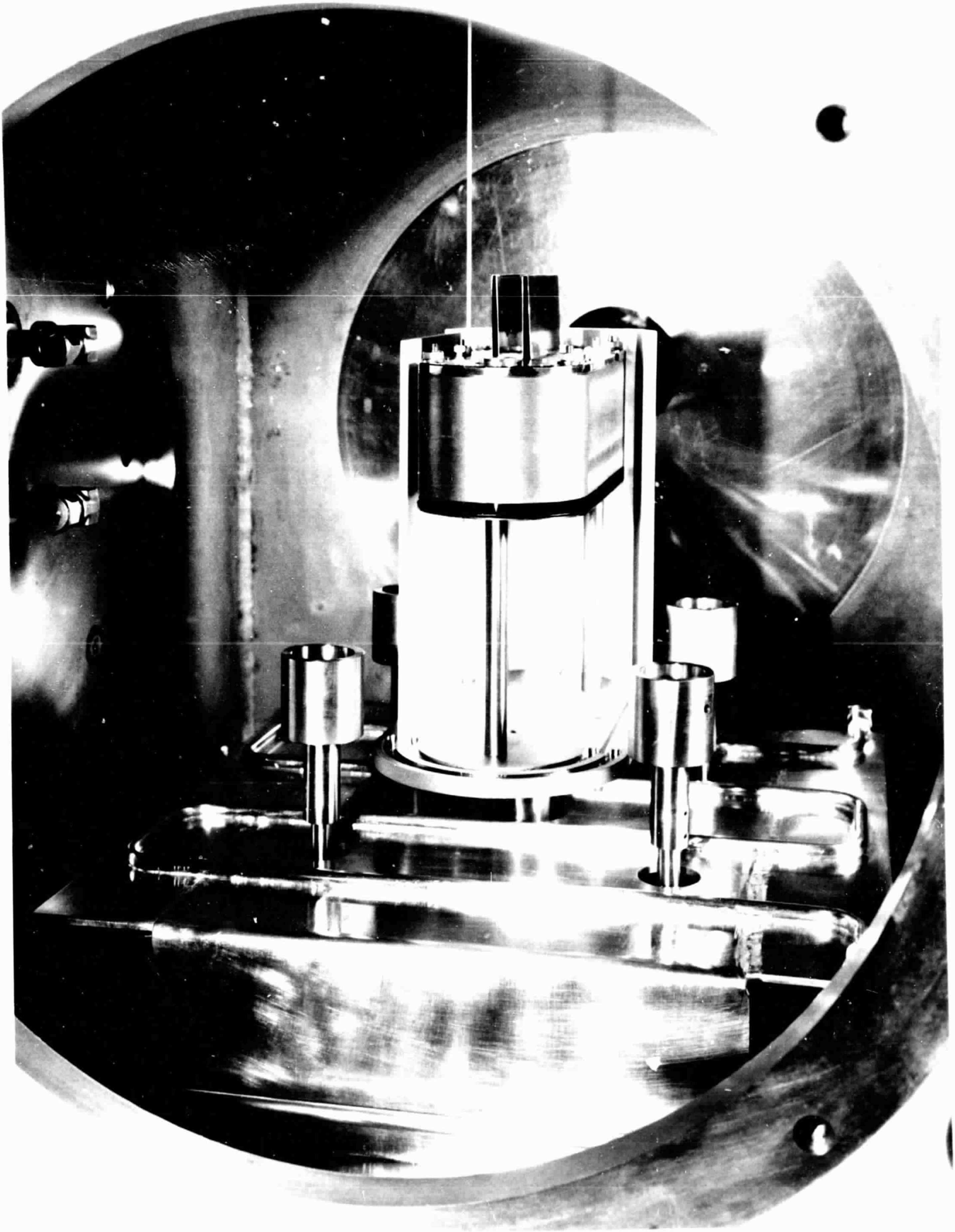


Fig. 9. Silicon web furnace (interior view: front)



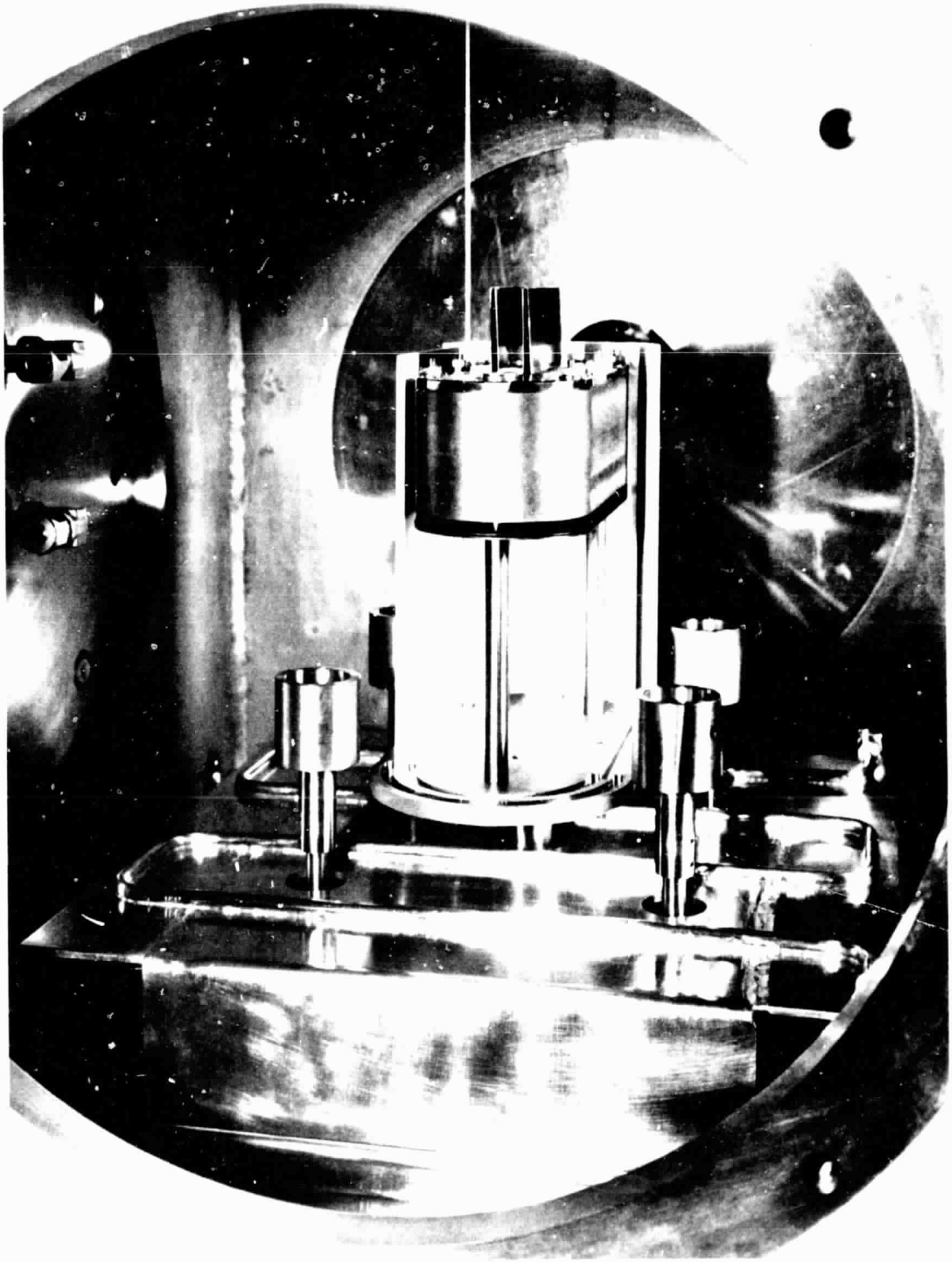


Fig. 10. Silicon web furnace (interior view: side).

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APPENDIX A

DESIGN DRAWINGS

This appendix includes the Design Specifications ("D-Spec") and reduced copies of all detailed drawings necessary for the fabrication and assembly of the Silicon Dendritic Web Growth Furnace.

ROUTING					
FIREPROOF VAULT					

DRAWING LIST

INDEX	LINE	TITLE OF DRAWING	DRAWING NO.	MULTIPLIER	ITEMS OR STYLE NO.	CHECKED	DATE CHECKED
	1	CHAMBER & FRAME ASSY	767J593				
	2						
	3	CHAMBER BOX WELD'T	639F431				
	4	FRAME	639F434				
	5						
	6	BOX DETAILS	8504D21				
	7	COIL LIFT DETAILS	8504D35				
	8	COIL LIFT DETAILS	8504D41				
	9	COIL LIFT DETAILS	8504D42				
	10	TOP ℞ COIL LIFT ASSY	8504D52				
	11	MID ℞ COIL LIFT ASS'Y	8504D53				
	12	BOT ℞ COIL LIFT ASSY	850[illegible]D54				
	13	WORK COIL VERT ADJ	8504D76				
	14	WORK COIL HORIZ ADJ	8504D77				
	15	CRUCIBLE POST DET	8504D98				
	16	COVER DETAILS	8506D46				
	17	COIL DETAILS	8506D56				
	18	COIL DETAILS	8506D58				
	19	DETAILS	8506D61				
	20	BALANCE DETAILS	8506D69				
	21	BALANCE ASS'Y	8506D70				
	22	CRUCIBLE SHL'D & POST ASSY	8506D75				
	23	CRUCIBLE & SUSCEPTOR	8506D79				
	24	CRUCIBLE & SUSCEPTOR ASSY	8506D80				
	25						
	26	KNOB DETAILS	257C034				
	27	ROD HSG SUB-ASSY	257C074				
	28	BACK COVER WELDMENT	257C251				
	29	COIL & ROUGHING PUMP ASSY	257C261				

STOCK ORDER (1ST S.O. ON WHICH INF. HAS BEEN SENT TO SHOP) | IDENTIFYING DATA: IN SPECIFYING THIS D NO. ON A STOCK ORDER THE ENGINEER MUST GIVE: –

NAME OF APPARATUS: SILICON WEB FURNACE

ENGINEER S. DUNCAN

CHECKED BY AND DATE: W. C. SUMPMAN — 7-9-75 — 12-5-75

DESIGN SPEC. D 902983

SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER
A	B			

WESTINGHOUSE FORM 6541 J

PAGE 1 OF 2

SUB. LETTER	SUB. LETTER	SUB-LETTER	SUB. LETTER	SUB. LETTER

ROUTING						
FIREPROOF VAULT						

DRAWING LIST

INDEX	LINE	TITLE OF DRAWING	DRAWING NO.	MULTI-PLIER	ITEMS OR STYLE NO.	CHECKED	DATE CHECKED
	1	GEN. ASS'Y.	767J599				
	2						
	3						
	4	STORAGE REEL-DET.	8506D39				
	5	RIBBON GUIDE-DET.	8506D77				
	6	STORAGE REEL-DET.	8507D10				
	7	STORAGE REEL-DET.	8507D11				
	8	STORAGE REEL SUP.	8507D19				
	9	RIBBON GUIDE ROLL	8507D32				
	10	WEB WITHDRAWAL DT.	8507D33				
	11	FEED SPOOL HSG.	8507D50				
	12	FEED TUBE DET.	8507D52				
	13	FEED TUBE DET.	8507D63				
	14	DET'S.	8507D68				
	15	SUB. ASSY'S.	8507D69				
	16	SUB. ASSY'S.	8507D71				
	17	FEED TUBE SUB.ASSY.	8507D97				
	18	DET'S.	8507D99				
	19	STORAGE RL. SUB.ASSY.	8508D02				
	20	DET.	8508D18				
	21						
	22						
	23						
	24	ALT. STORAGE REEL	257C504				
	25	SUB.-ASSY'S.	257C334				
	26						
	27						
	28						
	29						

STOCK ORDER (1ST S.O. ON WHICH INF. HAS BEEN SENT TO SHOP) | IDENTIFYING DATA: IN SPECIFYING THIS D NO. ON A STOCK ORDER THE ENGINEER MUST GIVE: —

NAME OF APPARATUS: SILICON WEB FURNACE

ENGR. S. DUNCAN

CHECKED BY AND DATE					
W. C. SUMPMAN	12-5-75				
DESIGN SPEC. D 902983	SUB. LETTER A	SUB. LETTER	SUB. LETTER	SUB. LETTER	SUB. LETTER
WESTINGHOUSE FORM 6541 J — PAGE 2 OF 2	SUB. LETTER	SUB. LETTER	SUB-LETTER	SUB. LETTER	SUB. LETTER